SpaceWire as a CubeSat Instrument Interface

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Overview

- Introduction
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- Physical Implementation
- Software Implementation
- Protocols
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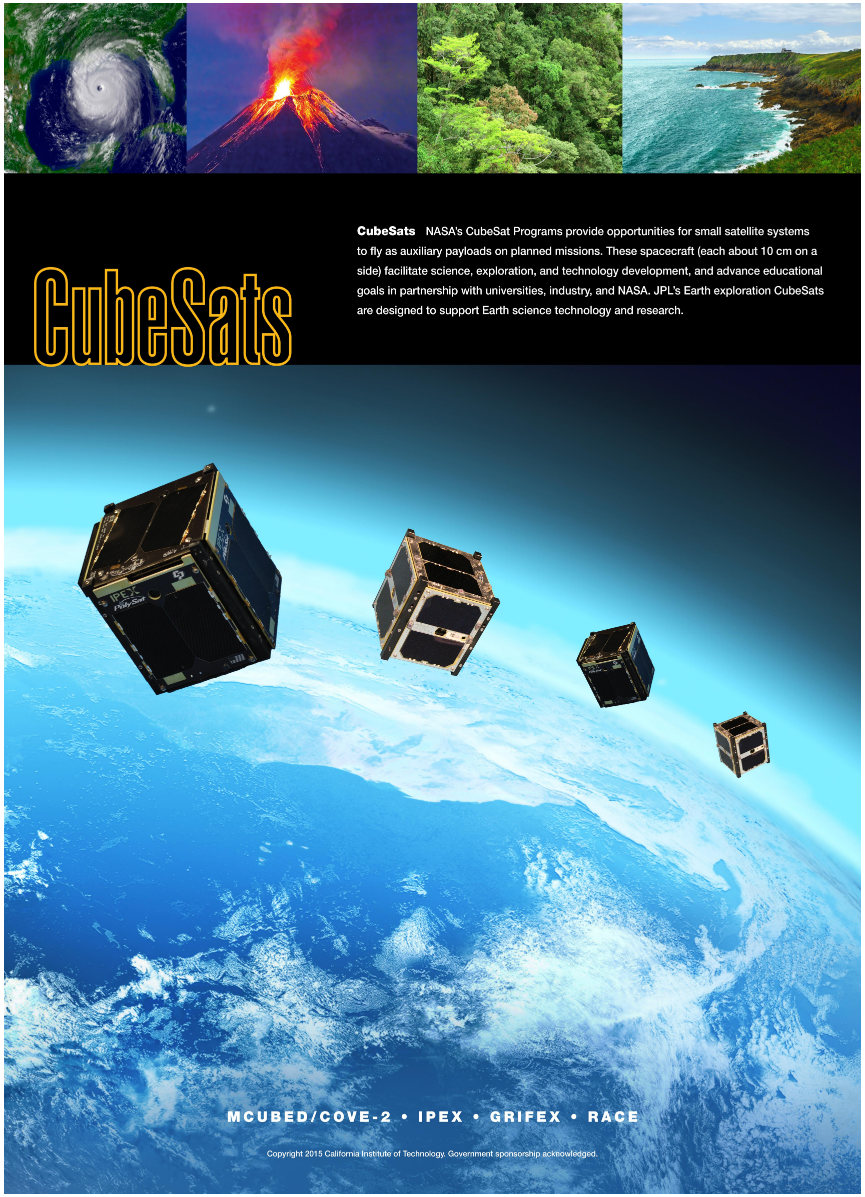
- Test Software
- Conclusions and Future Work



CubeSats

CubeSats NASA's CubeSat Programs provide opportunities for small satellite systems to fly as auxiliary payloads on planned missions. These spacecraft (each about 10 cm on a side) facilitate science, exploration, and technology development, and advance educational goals in partnership with universities, industry, and NASA. JPL's Earth exploration CubeSats are designed to support Earth science technology and research.

MCUBED/COVE-2 • IPEX • GRIFEX • RACE

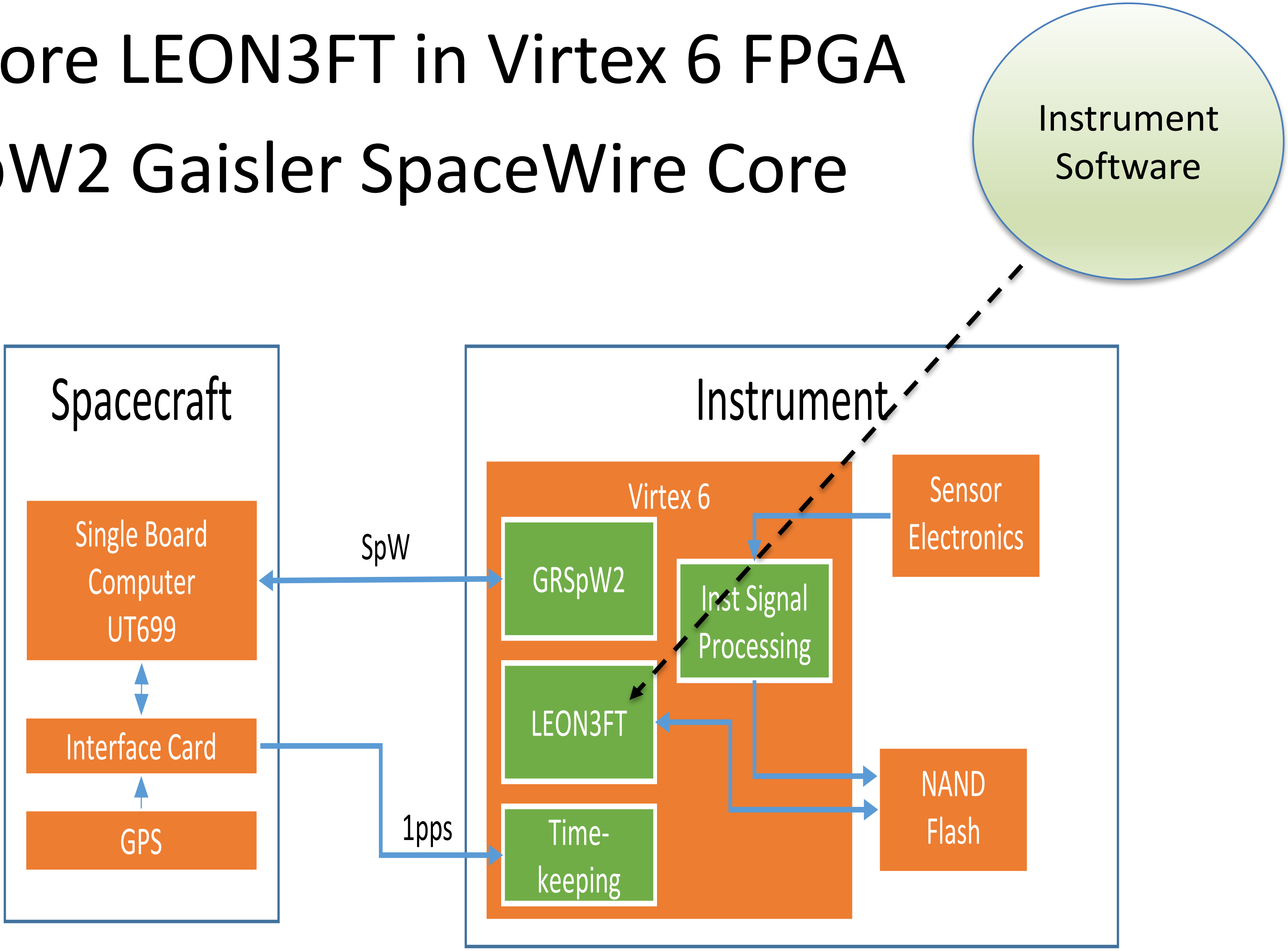
SpaceWire On CubeSats - Background

- Spacewire was used for the control and data interface on a CubeSat instrument
  - SpaceWire was chosen because
    - fits the CubeSat size, weight, and power restrictions
    - Availability of vendor supplied SpaceWire FPGA core and software device drivers, SpaceWire flight parts, and SpaceWire test equipment

- Instrument Collects and Stores data in flash
- Streams data from flash to CubeSat spacecraft

SpaceWire On CubeSats – Physical Implementation

- Softcore LEON3FT in Virtex 6 FPGA
- GRSpW2 Gaisler SpaceWire Core

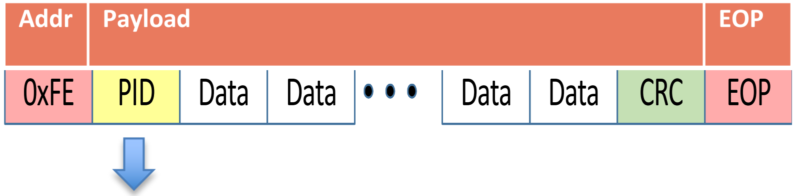


SpaceWire On CubeSats – Software Implementation

- Instrument software runs under RTEMS
- Augmented the RTEMS shell with instrument specific command / response API
- Implemented POSIX threads for
  - SpaceWire Transmit / Receive Interface
    - Used Gaisler SpW2 Device Driver low level interface
  - Instrument control and data collection
- Data is time-tagged with GPS Time

SpaceWire On CubeSats – Protocol

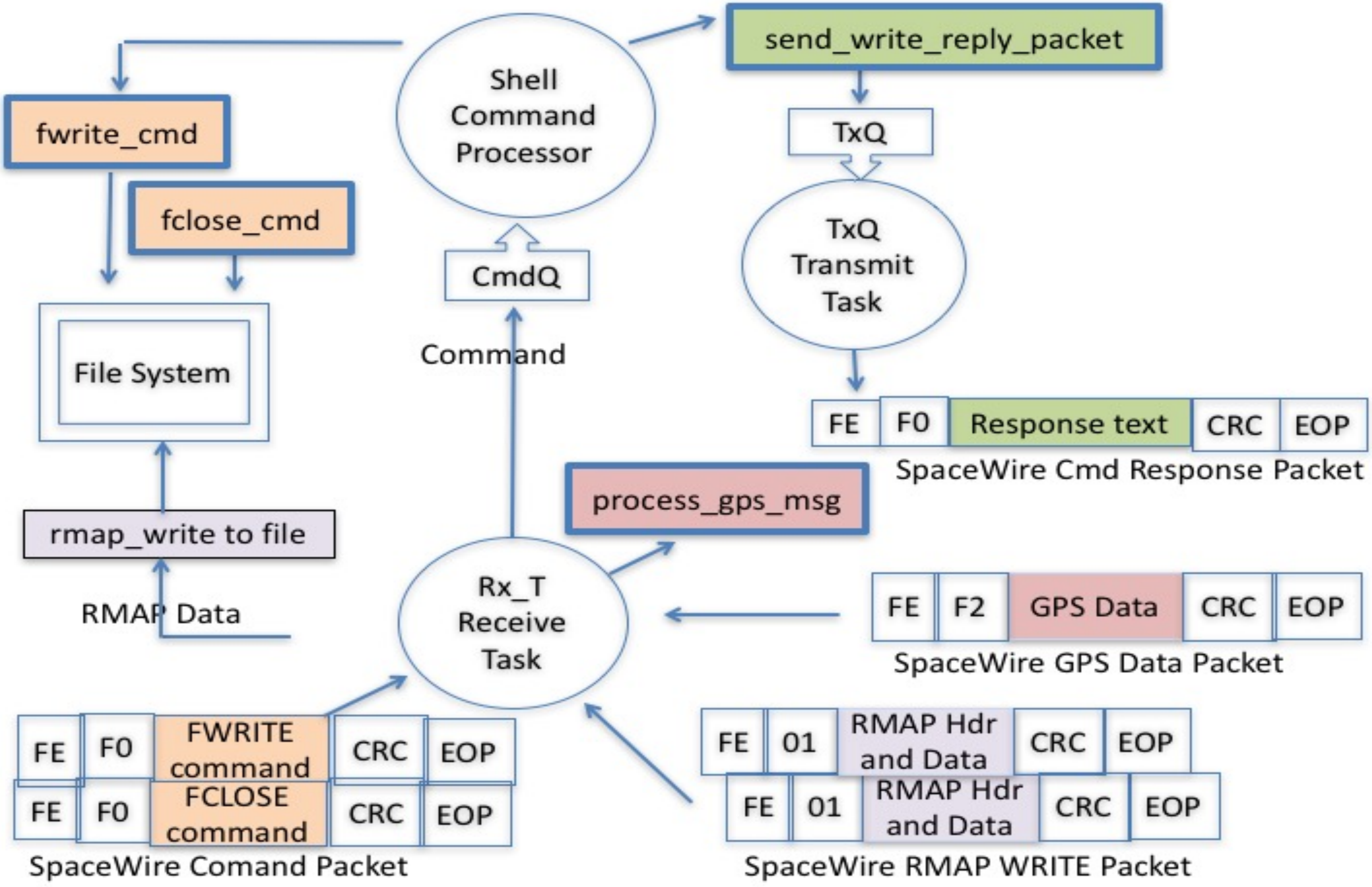
- Defined four SpaceWire message types
  - ASCII text based command / response API
  - Used existing well defined formats for
    - transferring files (RMAP)
    - instrument data (VITA-49)
  - GPS Time Message



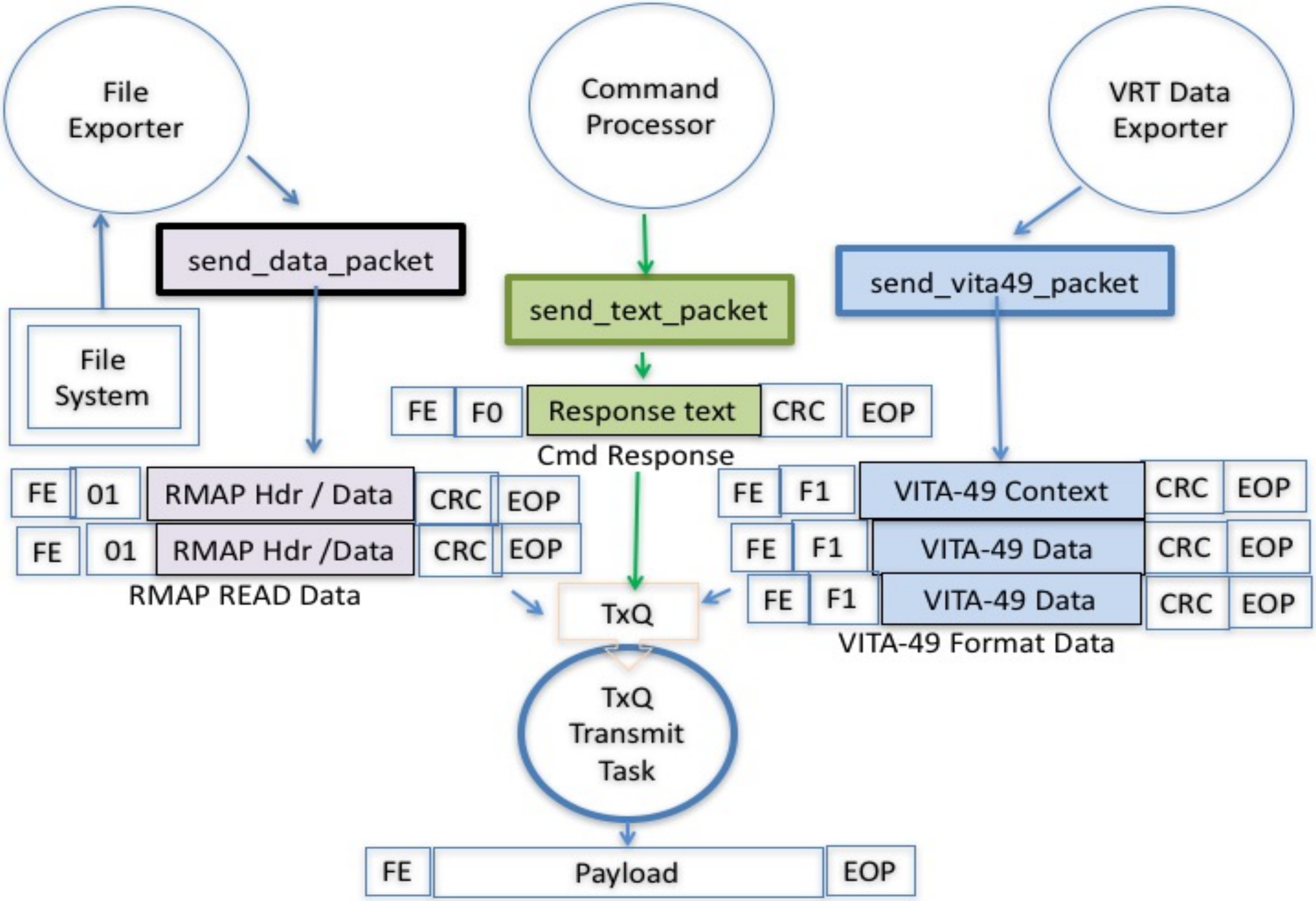
Addr	Payload							EOP
0xFE	PID	Data	Data	• • •	Data	Data	CRC	EOP

PID	PROTOCOL ID DESCRIPTION
0x01	RMAP – used for file and binary data transfer to/from the instrument
0xF0	text (ASCII) data to from the instrument (stdin, stdout)
0xF1	Sampled Data as VITA-49 packets returned from the instrument
0xF2	GPS Binary message to the instrument

SpaceWire On CubeSats – Receive Protocol



SpaceWire On CubeSats – Transmit Protocol



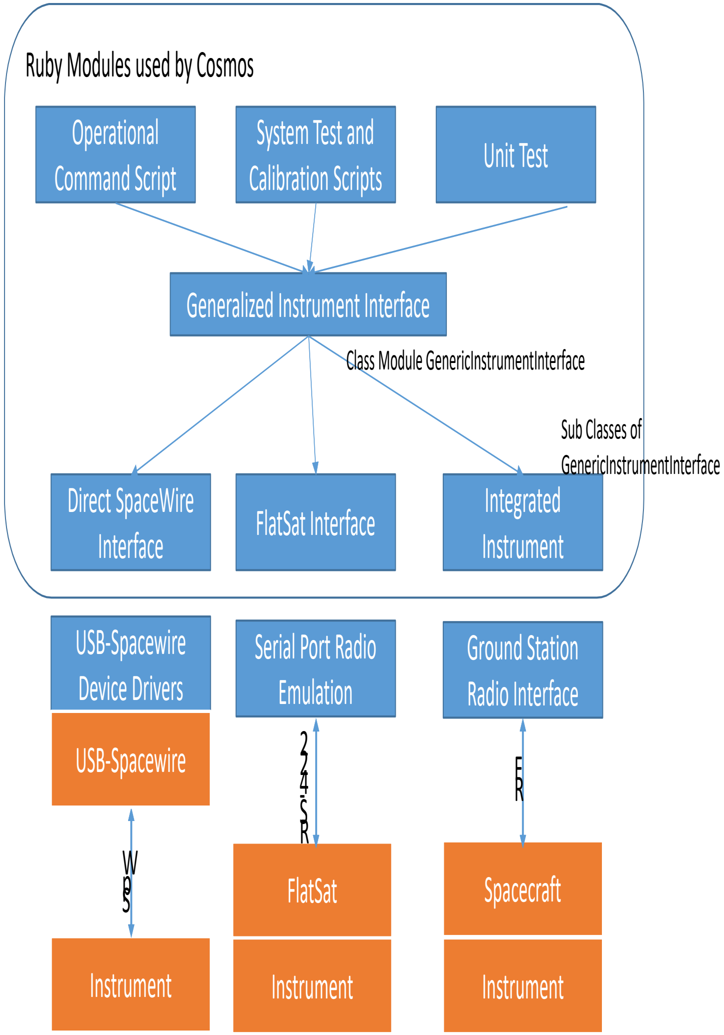
SpaceWire On CubeSats – Spacewire API

- Abstracted the SpaceWire interface using a simple API for sending / receiving messages

SpaceWire API Function	Description
spacewire_init()	Initialize SpaceWire interface
send_data_packet(len,tid,buf)	Send an RMAP data packet
send_text_packet(len,buf)	Send VITA-49 packet
send_vita49_packet(len,buf)	Send VITA-49 packet
send_write_reply_packet(len,buf)	Send fwrite reply
set_fwrite_params(fn,fsize)	Updates file IO name and size
write_packet_to_file(pkt)	Decodes and writes RMAP data
dump_packet(buf,len)	Outputs packet in ASCII text (for debug)

SpaceWire On CubeSats – Test Software

- Test Configurations
  - Test Bench Configuration
    - Developed send/receive tool to support the HW/SW development and test
    - Star-Dundee SpaceWire USB brick and software driver
  - FlatSat Configuration
    - COSMOS – cmd and control software, Ruby test scripts
    - FlatSat Interface via Serial Port
  - Spacecraft Configuration
    - Ground Station Software
    - RF uplink/downlink to Spacecraft
    - SpaceWire from Spacecraft to Instrument


Ruby Modules used by Cosmos
Operational Command Script
System Test and Calibration Scripts
Unit Test
Generalized Instrument Interface
Class Module GenericInstrumentInterface
Sub Classes of GenericInstrumentInterface
Direct SpaceWire Interface
FlatSat Interface
Integrated Instrument
USB-Spacewire Device Drivers
Serial Port Radio Emulation
Ground Station Radio Interface
USB-Spacewire
SpW
RS-422
RF
FlatSat
Spacecraft
Instrument
Instrument
Instrument

Conclusions and Future Work

- Conclusions
  - Early development and test with commercial off-the-shelf products with good documentation can accelerate development, integration and delivery
  - Use of a simple command and response interface with adoption of existing protocols for formats reduces the effort to design, implement, document, and test

- Future Work
  - Proposing use of SpaceWire in technology demonstrations to reduce the cost, effort, and risk of using SpaceWire on future planetary missions

Resources

- Email: Susan.Clancy@jpl.nasa.gov
- CubeSat Info https://www.cubesat.org/
- SpaceWire RMAP Info:
  - https://www.star-dundee.com/knowledge-base/rmap-explained
- GRSPW2 SpaceWire Info:
  - https://www.gaisler.com/index.php/products?option=com_content&task=view&id=276
- Ball Aerospace COSMOS Info:
  - https://cosmosrb.com